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THERMAL RESPONSE OF LARGE AREA HIGH TEMPERATURE SUPERCONDUCTING YBaCuO INFRARED BOLOMETER

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ABSTRACT:

Thermal analysis of large area high temperature superconducting infrared detector operating in the equilibrium mode (bolometer) was performed. An expression for the temperature coefficient $\beta=1/R(dR/dT)$ in terms of the thermal conductance and the thermal time constant of the detector were derived. A superconducting transition edge bolometer is a thermistor consisting of a thin film superconducting YBaCuO evaporated into a suitable thermally isolated substrate. The operating temperature of the bolometer is maintained close to the midpoint of the superconducting transition region where the resistance R has a maximum dynamic range. Measurements on the electrical response of YBaCuO thin films to a fast optical laser pulses (100Ps long) was recently reported[1]. It was found that although the magnitude of the signal corresponds to radiation heating, nonequilibrium energy transport have played a part in distributing the heat through the thickness of the film. A thermal diffusion model was developed to explain the experimental observations and to describe the overall thermal response of large area detector to external excitations. The results of these simulations agree reasonably well with the reported measurements. In this approach a detector with a strip configuration (see Fig.1) was analyzed and an expression for the temperature rise ΔT above the ambient due to a uniform illumination with a source of power density P_i was calculated to be,

$$T=(P_i t_h/C\Gamma)(1-\exp(-t/t_h)) \qquad (1)$$

where t_h is the thermal time constant of the detector, C is the volume specific heat, and Γ is the mass density of the thin film. the temperature rise in equation (1) was converted into voltages using R aganist T data provided in Ref.1 and the bias current of the thin film. The results of these calculations together with the measurements of Ref.1 are shown in Fig.2. On the other hand an expression for the thermal responsivity of the detector was derived using the above thermal diffusion analysis with appropriate boundary conditions. It was found that the thermal

responsivity depends upon the spatial modulation frequency and the angular frequency of the incoming radiation. For a given material with its characteristic diffusivity value, higher chopping frequencies will result in higher spatial frequencies to produce the same thermal response while quadrupling the chopping frequencies requires doubling the spatial frequency. The response of the HTS detector will ultimately be determined by tradding off the electrical-thermal gain bandwidth and the noise bandwidth. the bandwidth limits are determined by the thermal time constant t_h and the electrical time constant t_e and the signal rise time will be affected by the thermal coupling between the film and the insulator substrate.

The problem of the thermal cross talk between different detector elements was addressed. In the case of monolithic HTS detector array with a row of square elements of dimensions 2a and CCD or CID readout electronics the thermal spread function was derived for different spacing between elements. It was found that the thermal cross talk decreases rapidly with increasing the spacing between elements in the array. This analysis can be critical for future design and applications of large area focal plane arrays as broad band optical detectors made of granular thin films HTS YBaCuO.

References

1) W.R. Donaldson et al, "Interactions of picosecond optical pulses with High-Tc superconducting films" submitted to Appl.Phys.Letters, February 23, 1989.

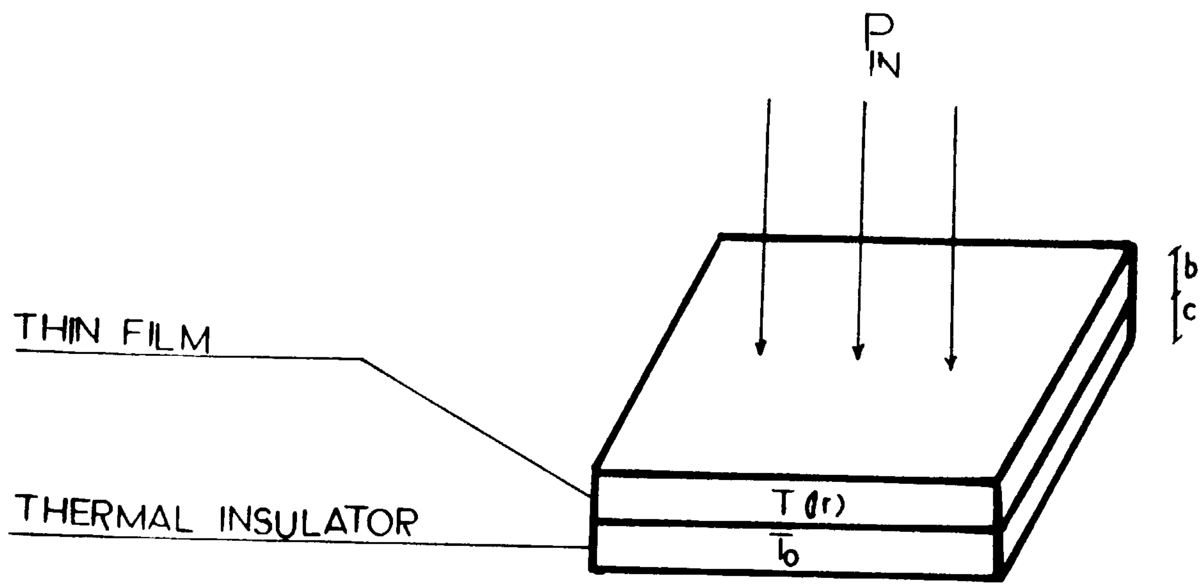

FIG. 1

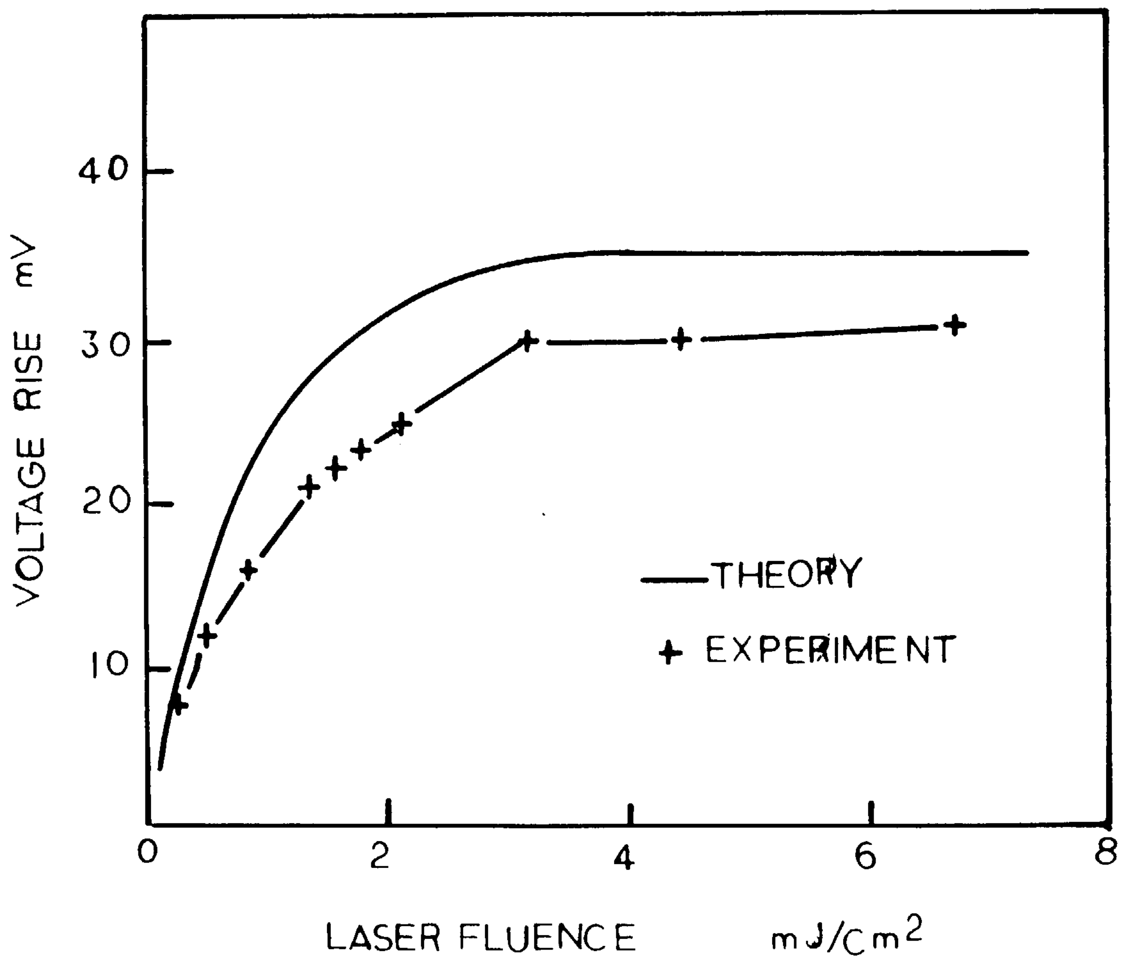
40
30
20
10
VOLTAGE RISE mV
0
2
4
6
8
LASER FLUENCE mJ/cm2
THEORY
EXPERIMENT

FIG. 2

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